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Meteorology

4770 Meteorology (Particles and Aerosols)
BACKGROUND TROPOSPHERIC AEROSOLS: INCORPORATION WITHIN A STATISTICAL-DYNAMICAL CLIMATE MODEL
G. L. Potter (Atmospheric and Geophysical Sciences Division, Lawrence Livermore National Laboratory, Livermore, California, 94550), R. D. Cess (Laboratory for Planetary Atmospheres Research, State University of New York, Stony Brook, New York, 11794)
To evaluate the possible influence of natural background tropospheric aerosols upon the earth's present climate, we have incorporated aerosol radiation models for continental and maritime aerosols into the Lawrence Livermore National Laboratory statistical-dynamical climate model. The model results suggest that background tropospheric aerosols produce 3-4 °C global surface cooling, with maximum cooling occurring at high latitudes, results which are essentially consistent with an energy-balance climate model study by Coakley et al. [J. Atmos. Sci., 40, 116-138, 1983].
To specifically delineate effects caused directly by the aerosols, as opposed to indirect effects resulting from aerosol induced climate change, a second climate perturbation was considered which consisted of reducing the solar constant so as to give exactly the same initial reduction in surface-atmosphere solar absorption as for the inclusion of tropospheric aerosols. These separate climate perturbations produced nearly identical climate feedback effects, together with similar changes in atmospheric stability and hydrological cycle, despite the fact that the two perturbations have quite different latitudinal and vertical distributions. This finding is consistent with a general circulation model study by Manabe and Wetherald [J. Atmos. Sci., 37, 99-118, 1980] concerning perturbations of both atmospheric CO_2 and the solar constant. A related conclusion is that the model's climate response to tropospheric aerosols is insensitive to the manner in which the aerosols are vertically distributed. (Aerosols, climate model, tropospheric aerosols, climate model sensitivity).
J. Geophys. Res., D, Paper 4D0751

Oceanography

4710 Chemical Oceanography
FACTORS INFLUENCING THE DEGREE OF SATURATION OF THE SURFACE AND INTERMEDIATE WATERS OF THE NORTH PACIFIC WITH RESPECT TO ARAGONITE
R. A. Feely (Pacific Marine Environmental Laboratory, NOAA, 7600 Sand Point Way N.E. BIN C15700, Seattle, Washington, 98115), R. H. Byrne, P. R. Betzer, J. F. Gendron, and J. G. Acker
New carbonate chemistry data obtained during the 1982 NOAA cruise have been combined with earlier GEOSECS and INDOPAC data to determine the degree of aragonite saturation of the surface and intermediate waters of the North Pacific. Large gradients in saturation state occur in the region of the Subarctic Front, in the north-south direction and across the Subtropical Gyre in the east-west direction. These gradients are primarily due to the extensive mixing that occurs in the intermediate waters of the western North Pacific. The major variations noted for the saturation state of these waters were primarily related to the carbonate ion concentration which, in turn, is primarily a function of mixing and biological processes. The present aragonite saturation depth at our northernmost station in the western North Pacific was calculated to be within 120 meters of the surface. This result was directly corroborated by observations of aragonite dissolution under in-situ conditions. Our calculations show that one possible effect of fossil-fuel-derived CO_2 on the surface ocean of the North Pacific will be a steady progression of undersaturation from the northern North Pacific to the southern and western North Pacific, with the first sign of undersaturation possibly occurring as early as the second half of the next century.
J. Geophys. Res., C, Paper 4C0684

4713 Circulation
SUBINERTIAL CURRENT OSCILLATIONS IN WESTERN LONG ISLAND SOUND
D. S. Ullman and S. E. Wilson (Marine Sciences Research Center, SUNY at Stony Brook, Stony Brook, NY, 11794)
The spatial structure of subinertial current fluctuations in a section across western Long Island Sound is investigated using the method of empirical orthogonal functions. The variability in the deeper areas of the section is found to be dominated by a set up response to the longitudinal wind. Towards the southern side of the basin, much of the variance cannot be explained by this mechanism. Spectral analysis indicates that the currents in this area have increased short period variance, with periods between 40 and 55 hours, and tend to be highly polarized. A model of topographic waves in an infinite channel with a symmetric exponential bottom profile is shown to predict the polarization and cross channel structure of velocity fluctuations in this band. High rotary coherence between counterrotating current and wind components in this band, where the group velocity of the wave is nearly zero, suggests the possibility of a resonant response to wind forcing.
J. Geophys. Res., C, Paper 4C0687

4720 Distributions and Water Masses
THE STRATIFICATION AND WATER MASSES AT DRAKE PASSAGE
Hellmuth A. Sievers and Worth D. Nowlin, Jr. (Oceanography Department, Texas A&M University, College Station, Texas, 77843)
The waters at Drake Passage are known to be separated horizontally into 4 distinct zones of relatively small baroclinic shear by 3 fronts in which the shear and eastward flow are large. The two northern fronts, Subantarctic Front and Polar Front, which bound the Polar Frontal Zone comprise most of the transport of the Antarctic Circumpolar Current.
Vertical sections of closely spaced (~50 km) oceanographic stations made across Drake Passage in the summers of 1975 and 1976 produced quality measurements of temperature, salinity, oxygen, silicate, nitrate and phosphate. Based on these data, a traditional description of characteristic distributions is presented. Good sampling resolution in the vertical allows maxima in hydrostatic stability to be traced laterally (approximately along isopycnals) between individual stations. Eleven strata of maximum stability are identified. Most vertically separate distinct water masses.
The most pronounced stability stratum is associated with the seasonal pycnocline; north of the Polar Front it separates the Subantarctic Surface Waters from Subantarctic Mode Water. To the south of the Polar Front the seasonal pycnocline is found slightly above the temperature minimum characteristic of the Antarctic Surface Waters in austral summer. This stability stratum extends northward near the base of the Subantarctic Mode Water. Another stability stratum extending across the entire passage forms the upper boundary for the Circumpolar Deep Water. South of the Polar Front, this stratum is at the base of the Antarctic Surface Water; to the north, it is the lower boundary of the Antarctic Intermediate Water. Although Subantarctic Mode Water and Antarctic Intermediate Water are separated by a stability stratum north of the Polar Front, there is no such separation between Antarctic Intermediate Water and the temperature minimum of the Antarctic Surface Water south of the front. This suggests that Subantarctic Mode Water and Antarctic Intermediate Water are distinct, and that the latter derives from the surface waters of the Polar Front.
At greater depths, a horizontally discontinuous stratum is found between the Upper and Lower Circumpolar Deep Water. Two horizontally continuous stability strata are found near the base of the Circumpolar Deep Water marking the transition to a high-silicate variety of denser deep water from the Southeast Pacific Basin. The densest water seen found is Weddell Sea Deep Water which flows through a gap in the South Scotia Ridge and along the southern Scotia Sea to fill the trough in the southern Drake Passage. It is overlain by a laterally continuous stratum of relative maximum stability. (Southern Ocean, general circulation, water masses, vertical stratification).
J. Geophys. Res., C, Paper 4C0935

4725 Estuaries, Bays and Fjords
OBSERVATIONS OF WIND-INDUCED, SUBTIDAL VARIABILITY IN THE DELAWARE ESTUARY
Kuo-Chuin Wong and Richard W. Garvine (College of Marine Studies, University of Delaware, Newark, DE 19716)
Sea level and current observations made in the Delaware estuary during autumn of 1982 were examined for evidence of wind-forced subtidal variability. The large subtidal sea level fluctuations at the mouth of the Delaware were found to be forced primarily by the wind stress component over the continental shelf nearly parallel to shore, indicating coastal Ekman transport to the right of the wind. Local wind forcing within the estuary is shown to be insignificant. The subtidal sea level in the interior of the estuary was found to be driven by the wind through a combination of two remote forcing mechanisms, one acting at the mouth of the Delaware through direct estuary-shelf coupling and a second acting locally over the Chesapeake Bay and transmitted from the upper Chesapeake through the Chesapeake and Delaware Canal which links the two estuaries. In the upper Delaware estuary we found predominantly barotropic subtidal current fluctuations superimposed on a much weaker two-layer gravitational circulation. These current fluctuations were produced primarily by the local subtidal surface slope generated by the difference between the two remote forcing mechanisms. The evidence strongly suggests that the Chesapeake and Delaware Canal plays a critical role in the subtidal circulation of the Delaware estuary.
J. Geophys. Res., C, Paper 4C0964

4760 Sea Ice
AN ESTIMATE OF THE MEAN FIELD OF ARCTIC SEA ICE MOTION
R. Colony (Polar Science Center, University of Washington, Seattle, Washington 98195) and A. S. Thorndike (Physics Department, University of Puget Sound, Tacoma, Washington 98416)
The general circulation of sea ice in the Arctic Ocean is estimated from daily track data. Since 1893 almost 100 station-years of drift data have been recorded. With the principles of optimal linear estimation this data is used to obtain a quantitative estimate of the field of mean motion. (general circulation, sea ice, drifting buoys)
J. Geophys. Res., C, Paper 4C0925

Particles and Fields—Interplanetary Space

5340 Shock Waves
SCALE LENGTHS IN QUASI-PARALLEL SHOCKS
J. D. Scudder (NASA/Goddard Space Flight Center, Lab. for Extraterrestrial Physics, Greenbelt, MD 20771), L. F. Burlaga and E. W. Greenstadt
Examples of an interplanetary and the Earth's bow shock are presented to illustrate the small scale of L_D of the fluid deceleration relative to the scale of the magnetic fluctuations, L_M, at quasi-parallel shocks. The increase in electron and ion random energies is also illustrated to occur on the short "inner" scale L_D. The selected interplanetary and bow shock examples are both supercritical high β shocks but with different Alfvén Mach numbers. The thickness L_D in absolute and adiabatic Larmor radii units of the lower Alfvén Mach number interplanetary shock is larger (≈ 10-13 U/Ω_i) than that at the bow shock (≈ 1-2 U/Ω_i) where U is the plasma flow speed viewed in the normally incident shock rest frame. In both examples the scale of the fluid deceleration is much smaller than that of the domain of up or downstream magnetic fluctuations. The existence of steady state quasi-parallel shocks requires a Lorentz deceleration force much larger than electrostatic deceleration force along the shock normal. (Parallel shocks, scale lengths, ion shocks, shock structure).
J. Geophys. Res., A, Paper 4A0842

Groundwater Occurrence and the Dissolution of Salt at the WIPP Radioactive Waste Repository Site

Lokesh Chaturvedi and Kenneth Rehfeldt[1]
Environmental Evaluation Group, Santa Fe, New Mexico 87503

Introduction

The Waste Isolation Pilot Plant (WIPP), located about 25 miles east of Carlsbad, in southeastern New Mexico, is slated to be the first deep geologic repository for permanent disposal of radioactive wastes in the United States. The repository will be located in bedded salt of Permian (225 m.y. B.P.) age, at a depth of 655 m below the ground surface. The present mission of WIPP calls for a permanent disposal of approximately 170,000 cubic meters of defense transuranic (TRU) wastes and for temporary, retrievable emplacement of 4.25 cubic meters of experimental high level wastes. The site will not be licensed by the Nuclear Regulatory Commission (NRC) but will comply with the Environmental Protection Agency (EPA) standards and all other federal and state regulations.

The site evaluation work for the WIPP has mostly been conducted since 1975 by Sandia Laboratories and the U.S. Geological Survey for the U.S. Department of Energy. On June 1, 1983, the Department of Energy (DOE) declared the site to be acceptable and announced its decision to proceed with the construction of the repository. Drilling of two shafts to a depth of 655 m and excavation of more than 3000 m of drifts has already been completed as part of the site and preliminary design validation (SPDV) program. Underground excavation is currently in progress to excavate the "rooms" where rock mechanics and heater experiments without radioactive materials will be conducted until 1988. The radioactive waste is scheduled to start arriving in 1989. The decision on whether or not to retrieve the TRU waste will be made 5 years after the first emplacement at WIPP. According to present schedule, the site will be decommissioned in 2006. This date primarily reflects the anticipated life of the mine shafts at WIPP.

The New Mexico Environmental Evaluation Group (EEG) conducts an independent review of all aspects of the WIPP project for the State of New Mexico. After a careful review of the results of site investigation, EEG [*Neill et al.*, 1983] has concluded that the site selected for WIPP has been characterized in sufficient detail to warrant confidence in its suitability, although additional work remains to be done to answer fully some remaining questions. These questions concern the hydrology and the mechanics and rate of salt dissolution. The DOE is committed to resolve these questions satisfactorily before bringing any radioactive waste to WIPP. The discussion that follows provides the background and outlines the need for further understanding of these questions

Geologic Setting

The WIPP site is situated in the northern part of the Delaware Basin, which is a sub-basin of the well-known Permian Basin of the southwestern United States. The Delaware Basin is bounded by a Permian reef, known as the Capitan Reef (Figure 1). The basin contains about 4300 m of Paleozoic sedimentary rocks overlying the Pre-Cambrian basement. The upper 1250 m consist of a sedimentary sequence belonging to the Ochoan Series (Upper Permian), the lower 1000 m of which consist of the three evaporite formations of interest to the WIPP. These three formations, from oldest to youngest, are Castile, Salado, and Rustler, respectively (Figure 2). Underlying the Ochoan series formations is the Delaware Mountain Group (DMC) formations which form the floor of the Delaware Basin evaporite sequence. The total thickness of the DMC is about 1200 m, but its upper member, the Bell Canyon, is most important for site evaluation because it is an aquifer. The horizon selected for WIPP is in the lower part of the Salado Formation, 655 m below ground level.

The site lies on a generally flat plain covered with sand and caliche and desert bushes. Two actively developing solution-erosion features lie west and east of the site. The one to the west, Nash Draw, is a dog-bone shaped subsidence feature 10–20 km wide in the east-west direction and about 30 km long (north-south). The eastern edge of Nash Draw lies 5 km west of the edge of the WIPP site (Figure 3). (Figure 3 shows the original boundary of WIPP, the outer fringe of which was abandoned by DOE in 1983. The presently planned repository is a 100 acre area south of ERDA-9. This area may be extended later but will remain within the inner octagonal area known as Zone II. Outside this is Zone III, where no surface mining or non-WIPP drilling will be allowed. A fenced area at the center (not shown in Figure 3) will house the administrative buildings and the shafts and is designated Zone I.)

[1]Now at Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139.

Geohydrology

The Rustler and the Bell Canyon formations contain poor quality groundwater under confined conditions. In addition, pressurized brine has been encountered in the upper part of the Castile Formation in several wells near the WIPP site (Figure 3). Since groundwater is the most likely mechanism for bringing radioactive waste from the WIPP repository to the biosphere, a detailed knowledge of the regional site specific groundwater conditions is necessary to assess the radiological consequences of breach of the repository. A summary of the characteristics of various aquifers at the site follows.

Bell Canyon Formation

Over the Delaware Basin as a whole, groundwater in the Bell Canyon Formation flows from west to east. In the vicinity of the WIPP site, flow is to the northeast. The unit is recharged along the western edge of the Delaware Basin, 90 km west of the site, where the Bell Canyon crops out. The unit appears to discharge into the Capitan Reef to the east (Figure 2).

The salinity of the Bell Canyon water increases from west to east. In the vicinity of the site, the total dissolved solids in the Bell Canyon range from 180 to 270 g/l. The water in the Bell Canyon is under artesian pressure and the potentiometric surface corrected to fresh water potential rises to ground level at the WIPP site.

Hydraulic head data are sparce and of questionable accuracy. In the vicinity of the WIPP site, only three boreholes have so far been used to collect Bell Canyon head data. A direct measurement of hydraulic head is available at only one well. At the other two, down hole pressure and fluid density were used to calculate the hydraulic head. It is planned to test this formation in three more boreholes during 1984–1985.

The hydraulic properties of the Bell Canyon vary considerably. The reported hydraulic conductivity values range from less than 10^{-7} cm/s to 2×10^{-4} cm/s and the porosity ranges from 4 to 30%. The calculated velocities, assuming a hydraulic gradient of 0.003, range from 1×10^{-9} cm/s to 1.5×10^{-5} cm/s. The mean travel time of an ideal conservative solute over a distance of 17 km (roughly the distance from the center of the WIPP to the Capitan Reef) ranges from 5.4×10^{7} years to 3.6×10^{5} years. After 3600 years the nuclides remaining are essentially Pu^{239}, Pu^{240}, and U^{233}. Lesser amounts of U^{234}, U^{235}, and U^{236} also remain. The movement of Pu is greatly retarded, at least in low concentrations, so the travel time of Pu is likely to be much longer than that of water. It appears, therefore, that if a repository breach released radionuclides into the Bell Canyon, the travel time of the nuclides would be so great that the resulting concentration of radioactivity in the water would be within acceptable limits at the Capitan Reef.

Castile Formation

The Castile Formation directly underlies the Salado formation where the repository will be located. The Castile is of interest because pressurized brine has been encountered in the upper anhydrite layer of the Castile in at least 13 out of more than 60 boreholes drilled to that depth in the northern Delaware Basin, including the WIPP site (Figure 3). The conclusion reached as a result of extensive hydraulic and chemical testing of two occurrences, one 1.6 km north of the center of the site (WIPP-12) and the other 7 km northeast of the center of the site (ERDA-6), is that the two boreholes intercepted separate reservoirs. However, although it would be incorrect to conclude that each of the 13 occurrences represents a separate brine reservoir, there is no indication that a brine "aquifer" exists in the Castile.

The brines are of concern because they are under anomalously high pressures. In WIPP-12, the pressure of the brine reservoir (encountered 930 m below the ground surface) is sufficient to support a column of brine extending more than 300 m above the ground surface. If a brine reservoir exists beneath the repository, then the potential for bringing radioactive material to the surface exists. EEG [*Channell*, 1982; *Bard*, 1982] has calculated the maximum radiation dose to an individual from a brine reservoir scenario to be below the limits that EPA Protective Action Guides recommend for low probability accidents. These calculations may change substantially if the type of radioactive wastes to be buried at WIPP is changed from that presently planned.

Rustler Formation

The Rustler Formation directly overlies the Salado Formation and contains three recognized fluid bearing zones. From stratigraphically lowest to highest, these are the Rustler-Salado contact residuum, the Culebra dolomite, and the Magenta dolomite. The transmissivity of the Culebra is highest, followed by the Magenta and the Rustler-Salado contact. The water quality is highly variable within each unit. The total dissolved solids concentration is lowest in the Magenta (the uppermost unit) and highest in the Rustler-Salado (the lowermost unit). Nearly all the water in the Rustler has TDS concentrations greater than 10,000 mg/l. The exception is the Culebra water south-southwest of the center of the WIPP site where the TDS is about 3,300 mg/l.

All three units probably discharge into the Pecos River 25 km southwest, near a bend in the river known as the Malaga Bend (Figure 1). The recharge areas are identified rather imprecisely as being upgradient of the measured hydraulic heads about 15–25 km north of the WIPP site. At the WIPP site the three units are separated but are probably interconnected in Nash Draw west and southwest of the site.

Of the three Rustler units, the Magenta and Culebra are of prime concern because they extend over the WIPP site, whereas the Rustler-Salado contact zone mainly produces water west of the WIPP site [*Gonzalez*, 1983; *Mercer*, 1983]. The majority of the testing in the Rustler has concentrated on the Culebra because it is more transmissive than the Magenta and therefore better suited for analyzing the worst case bounding breach scenarios.

The groundwater in the Magenta flows west from the site toward Nash Draw and then to the Pecos River near Malaga Bend. In and near Nash Draw the Magenta and Culebra appear to be hydraulically connected because the hydraulic head difference, over 30 m at the WIPP site, is only a few meters in Nash Draw. The direction of groundwater flow in the Culebra indicated by the potentiometric surface [*Mercer*, 1983] is south or southeast for 6–8 km and then to the west toward Malaga Bend. This apparent flow path is inconsistent with the observed chemistry. A marked change in the water chemistry in the Culebra aquifer occurs about 6.5 km south-west of the center of the site. The total dissolved solids to the southwest is much less than to the north. In addition, the water to the southwest is dominated by Ca^{2+}, Mg^{2+}, and SO_4^{2-}, whereas to the north the water chemistry is dominated by Na^+ and Cl^-. Comparing the subsets of Culebra water, the total Ca^{2+}, Mg^{2+}, and SO_4^{2-} differ by a factor of 2 or 3, whereas the Cl^- differs by factors of 8–1000. Therefore, a simple mixing of high TDS water with fresh recharge from precipitation does not explain the observed Culebra water chemistry.

The Capitan Reef

The Capitan Reef comprises one of the most productive freshwater aquifers in southeastern New Mexico. It surrounds the Delaware Basin in a horseshoe shape (Figure 1). At its closest point, it lies 16 km to the north of the WIPP site. Water that flowed eastward from this aquifer into the Bell Canyon combined with surface recharge into the Ochoan evaporite sequence of the Delaware Basin must have been responsible for the dissolution of salt in the basin. Whether or not this is an active process at the present time is a matter of controversy and a great deal of speculation. Some [e.g., *Anderson and Kirkland*, 1980; *Anderson*, 1981] believe that the Capitan Reef acts as a recharge source to the west and a discharge sink to the east and has thus facilitated the dissolution of salt in the evaporites at depth in the Delaware Basin. This point is further discussed below.

Extent of Salt Dissolution in the Delaware Basin

Bedded salt is a preferred medium for permanent emplacement of radioactive wastes because of the favorable physical, thermal, and mechanical properties of halite. However, halite is also readily soluble in water, and most bedded salt deposits have undergone different degrees of dissolution since their deposition.

In the area of the WIPP, there are several indications that a large amount of salt from both the Rustler and Salado formations has been dissolved away. To evaluate the impact of such dissolution on the nuclear waste repository of the WIPP, it is necessary to understand the horizontal and vertical extent as well as the time and rate of salt dissolution in Delaware Basin.

The regional dissolution of salt beds in the basin has progressed from west to east. It must have been initiated with the tilting of the basin to the east sometime during the Cenozoic era, which facilitated the injection of water from the Capitan Reef aquifer down-dip to the east into the Bell Canyon as well as surface flow into the evaporite deposits. In the western part of the Delaware Basin, the exposed Castile, Salado, and Rustler formations no longer contain any salt. The Salado, which before dissolution consists mainly of halite, is represented by a chaotic jumble of insoluble residue, less than one third the thickness. Even where the Salado is buried underground, most of the salt in it is probably represented by fractured anhydrite and breccia in the region designated as the "Area of Complete Removal of Salt" in Figure 1. In the area of "Salt Dissolution Zone" of Figure

Article (*cont. on p. 458*)

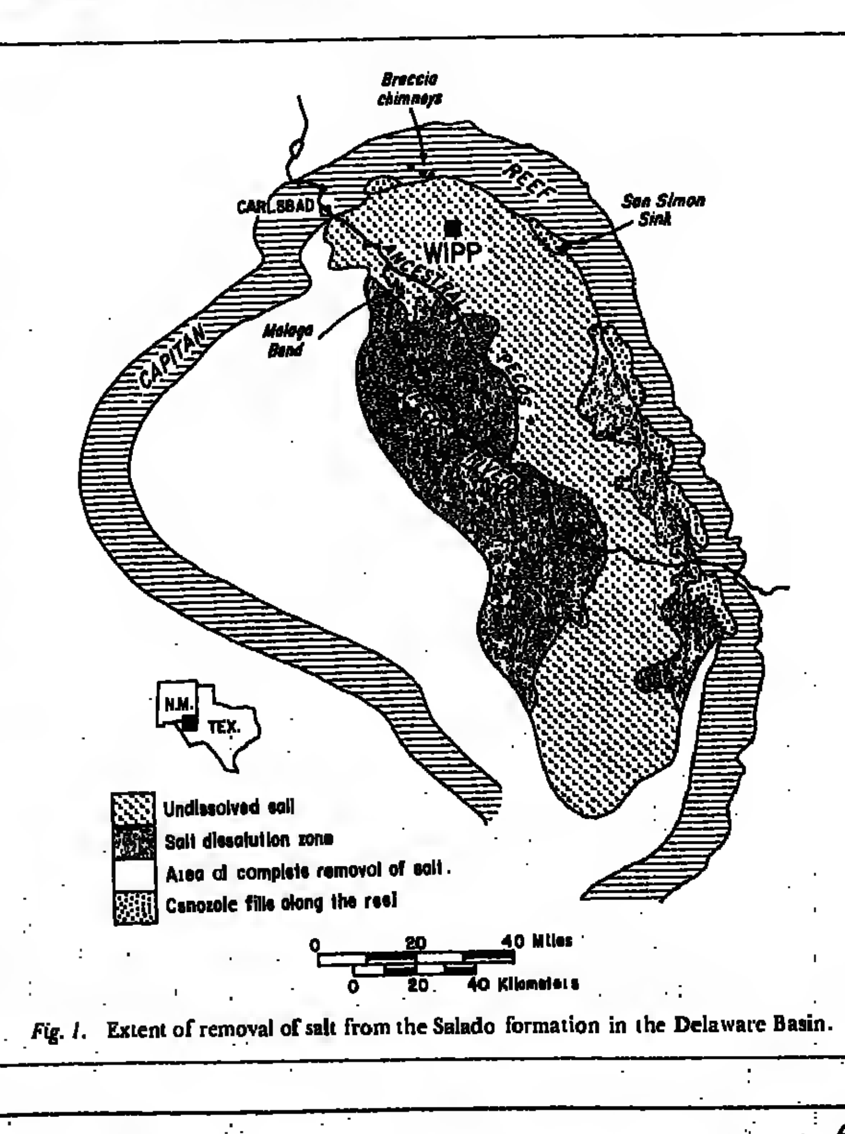

Fig. 1. Extent of removal of salt from the Salado formation in the Delaware Basin.

Article *(cont. from p. 457)*

1, the borehole logs indicate dissolution in the lower Salado and upper Castile [*Anderson*, 1982]. *Bachman* [1983] interprets the well logs to indicate dissolution breccia in lower Salado but not in Castile. The different interpretation stems from the difficulty in recognizing the Castile/Salado boundary.

The removal of halite by dissolution is observed in the Rustler Formation as well. Where unaffected by dissolution, the Rustler Formation is 150 m thick and contains about six discrete halite units with an aggregate thickness of about 40 m. Much of this halite has been removed over most of the WIPP site by dissolution. Directly above the selected repository area (Zones I and II) of the WIPP site, all the salt in the Rustler Formation, except a layer of argillaceous halite below the Culebra aquifer, has been removed by dissolution.

Mechanics of Dissolution

The earliest proposal for a specific mechanism of dissolution of salt in the Delaware Basin was made by *Lee* [1925]. His mechanism of "solution and fill" postulates infiltration of rain water collected in arroyos into the fractures of soluble rock. This results in the development of a drainage system a few feet below the surface, into which surface debris is carried by subsequent storms. As the gradient of the drainage system increases, headward cutting results. According to *Bachman* [1980], this process is currently active in Nash Draw, west of the WIPP site.

As stated above, salt has been removed from the Rustler Formation, which lies between 170 and 260 m below the ground surface at the WIPP site. The lowest affected zone is progressively deeper to the west. In the western part of the WIPP site and in Nash Draw, the top of Salado has also been affected by dissolution, and the permeable residuum thus formed contains brine at the Rustler/Salado interface. There are salt lakes in the southern part of Nash Draw and there are saline seeps along the Pecos River near Malaga Bend, about 25 km southwest of the WIPP site. These are thought to be the discharge points for the brine produced from the dissolution of Rustler halite.

A satisfactory explanation of the dissolution and removal of salt from the deeper strata is more problematical. There are at least three different schools of thought concerning the absence of halite in the lower Salado and Castile formations. On the basis of interpretation of accoustic logs from a large number of wells in the Delaware Basin, *Anderson* [1982] has concluded that about 50% of the salt in the Salado and Castile formations has been removed by dissolution, with as much as 70% of the original salt removed from the lower Salado horizon in the basin. For the mechanics of salt removal through "deep" dissolution, *Anderson* [1981] invoked a "brine density flow" model, which had been proposed earlier [*Anderson and Kirkland*, 1980] for the formation of breccia chimneys. This mechanism requires a connection between the lower Salado and the underlying Bell Canyon aquifer through fractures in the intervening Castile Formation. It was hypothesized that surface recharge moves into the evaporites, dissolves salt in the Salado and Castile formations, and the resulting brine sinks into the underlying aquifer. Thus, the postulated mechanism would continue as long as the supply of undersaturated water lasts and the fractured pathway remains unclogged. *Wood et al.* [1982] studied the potential dissolution mechanisms of diffusion and convection from the halite zones of Castile and Salado to the Bell Canyon and the Capitan Reef aquifers based upon a range of reported values for the hydrogeologic and geochemical parameters which influence salt removal. They concluded that the removal of dissolved salt through the Bell Canyon can take place only at a very slow rate, which would be grossly insufficient for removing approximately 7×10^{12} m^3 of salt from lower Salado in 1.5 million years, or about 4.7 million m^3 of salt per year (as estimated by [*Anderson*, 1981]). Even using the most conservative reported values for the hydraulic conductivity of the Bell Canyon, *Neill et al.* [1983] estimated that at most 20–50 times less salt would have been transported through the Bell Canyon than is estimated to have been removed.

The second explanation for the missing salt is provided by *Bachman* [1983]. According to him, major dissolution of the evaporites in the Delaware Basin has been restricted to areas where the Pecos River and its tributaries have initiated karst systems, or to limited areas which overlie the Capitan Reef aquifer. Figure 1 shows the path of an ancestral Pecos River, east of the present day Pecos, as postulated by *Bachman* [1983] on the basis of river gravel deposits left by this river. *Bachman* [1983] believes that this ancient system was responsible for the development of an extensive karst terrain now seen east of the present day river. The salt beds of the lower Salado Formation were selectively dissolved during the Cenozoic time as a result of a dissolution front which was perched on the upper anhydrite in the Castile Formation. *Bachman* [1983] further states that the Tertiary and Pleistocene hydrologic conditions no longer exist except along the present Pecos River channel, and therefore the probability of further dissolution in the proximity of the WIPP repository horizon is remote.

The third explanation for the missing salt in the lower Salado is that much of the missing salt simply represents a facies change or removal during a much earlier time soon after deposition. By drawing a composite isopach map of the Castile and lower Salado Formation, *Lambert* [1983] has shown that the "missing halite" areas commonly result in little or no departure from regional thickness of Castile and lower Salado evaporites. He therefore ascribes the observation of missing salt to several factors other than Cenozoic dissolution (e.g., depositional heterogeneities, perturbation of original bed thicknesses by localized deformation, and ambiguous identification of members or marker beds).

A serious problem encountered in explaining the removal of salt through dissolution is the disposition of the resulting brine. Anderson's brine density model requires the removal of brine through the Bell Canyon aquifer; but, as mentioned above, the Bell Canyon is thought to be incapable of acting as a sink for the large amount of brine produced from dissolution. *Bachman* [1983] has not even addressed the question of the disposal of solution brine. *Lambert* [1983] also has acknowledged the difficulty in postulating a viable sink for his stratabound dissolution model.

Time and Rate of Dissolution

Anderson [1981, 1982] maintains that most of the dissolution and removal of halite from the Salado and Castile evaporite beds in the Delaware Basin has occurred since the tilting of the basin to the east during the latter part of the Cenozoic, probably 4–6 m.y. ago. According to him, this event exposed the tilted limestone of the Capitan Reef as well as the sandstones of the Bell Canyon Formation which acted as suppliers of meteoric water to the lower part of the evaporites. Anderson has also used the correlation between the area of the bulk of the missing salt with the deep depressions filled with Pleistocene alluvial fill (described by *Maley and Huffington* [1953]) as evidence for most of the dissolution having taken place during late Cenozoic.

However, there exists some clear evidence of at least some dissolution having occurred in earlier geologic times. Some dissolution through subaerial erosion occurred prior to the deposition of Salado, during the Permian time. This is evident from the erosional unconformity that truncates Halite III bed of the underlying Castile formation. *Bachman* [1980] has proposed that the pre-Cenozoic times of nondeposition in the basin, mainly the Jurassic, must have been the times of extensive erosion and subsurface dissolution through circulation of meteoric water. *Anderson* [1981] disagrees with the concept of extensive pre-Cretaceous dissolution in the basin on the basis of the isopach maps of the middle and upper Salado showing regionally normal thickness trends extending westward to the area of present truncation. He points out that a truncation surface sufficient to allow pre-Cretaceous dissolution to reach into the Castile Formation would require a regional dip in the Cretaceous far greater than observed. *Bachman* [1983] believes that Tertiary and Pleistocene hydrologic conditions no longer exist except along the present Pecos River channel, and therefore the dissolution of halite in the lower Salado and Castile Formations is not an active process, at least near the WIPP site.

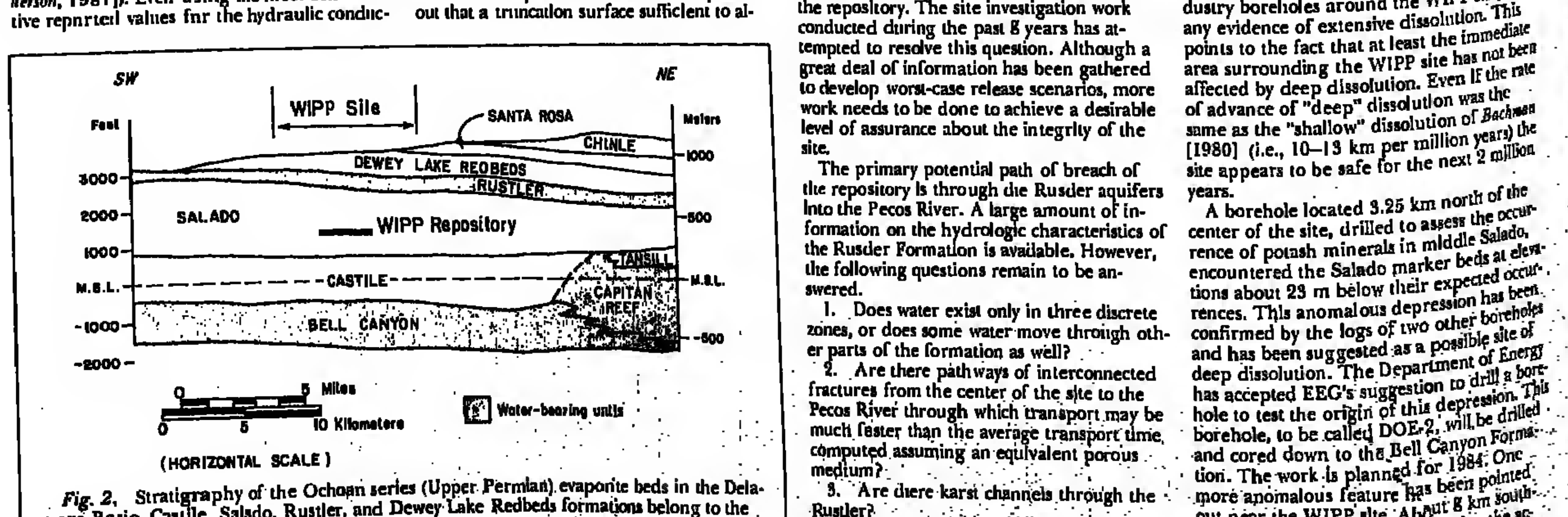

Fig. 2. Stratigraphy of the Ochoan series (Upper Permian) evaporite beds in the Delaware Basin. Castile, Salado, Rustler, and Dewey Lake Redbeds formations belong to the Ochoan Series.

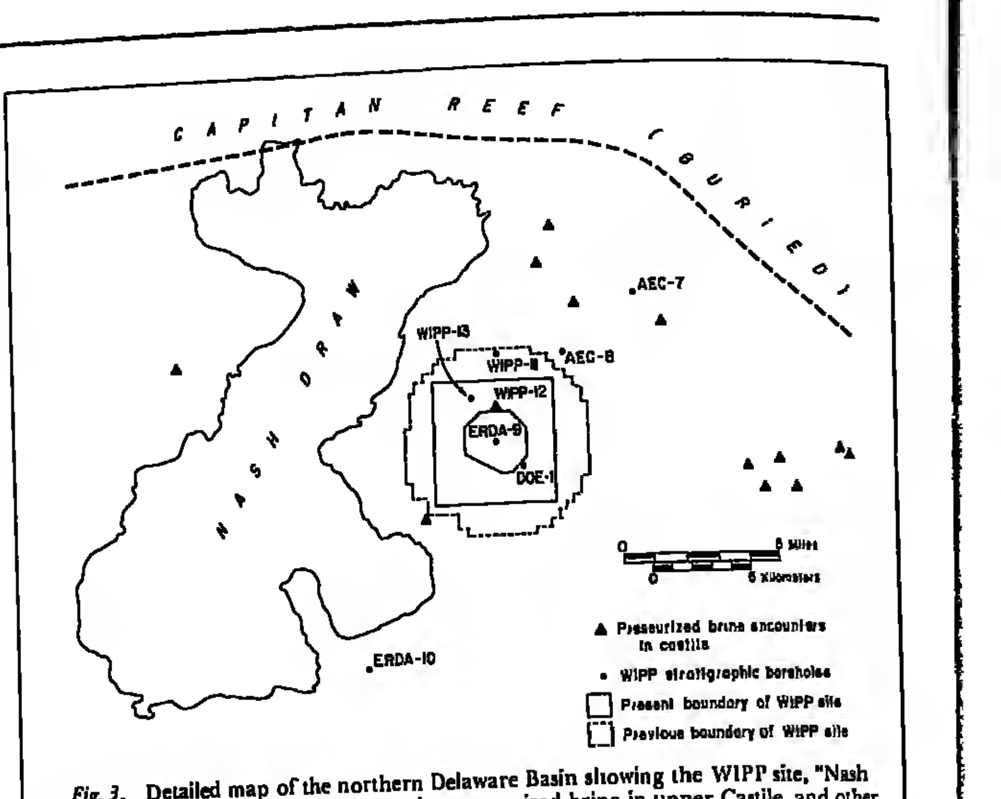

Fig. 3. Detailed map of the northern Delaware Basin showing the WIPP site, "Nash Draw" depression, boreholes encountering pressurized brine in upper Castile, and other deep stratigraphic boreholes drilled in connection with the WIPP project.

The easiest way to determine the safety of the WIPP site from the effects of deep dissolution would be to calculate an average rate of halite removal from the Delaware Basin and the distance of the dissolution front from the site. Assuming that the edge of the Salado salt has moved from the Capitan Reef front to its present location (Figure 1) during the past 7–8 million years, *Bachman and Johnson* [1973] concluded that the horizontal rate of movement of the blanket dissolution front is about 10–13 km per million years. Based upon the dating of a volcanic ash layer associated with the Pleistocene Gatuna Formation, which is exposed at the ridge on the eastern margin of Nash Draw, *Bachman* [1980] concluded that about 60 m of subsidence has occurred in this depresssion during the past 800,000 years. Using this rate, *Bachman* [1980] calculated an average rate of 100 m per million years for the vertical dissolution.

It is more difficult to determine the rates of advance of dissolution fronts for the deep-seated variety of dissolution. Such deep-seated undermining does not necessarily leave a discrete geomorphic feature such as a scarp. Anderson's assumption that the missing salt was removed by dissolution during late Cenozoic has been questioned. According to *Lambert* [1983], the tilting of the basin has not been precisely dated, but only estimated by *Hayes* [1964] as "late Cenozoic" in the total absence of geologic time markers. The occurrence of Gatuna sediments of Pleistocene age at the top of the fills in the *Maley and Huffington* [1953] depressions establishes the minimum age of the fill as Pleistocene. The deeper parts of these fills have not been studied to determine a maximum age for the fills, and therefore it is not reasonable to constrain the entire accumulation of the fills to the Pleistocene. However, the generally unconsolidated nature of these fills shows them to be of a recent geologic time period and their involvement in the regional salt dissolution process cannot be ruled out.

Integrity of the WIPP Site

The question of prime importance for the WIPP nuclear waste repository is whether there is a pathway for release of radionuclides to the biosphere in case of a breach of the repository. The site investigation work conducted during the past 8 years has attempted to resolve this question. Although a great deal of information has been gathered to develop worst-case release scenarios, more work needs to be done to achieve a desirable level of assurance about the integrity of the site.

The primary potential path of breach of the repository is through the Rustler aquifers into the Pecos River. A large amount of information on the hydrologic characteristics of the Rustler Formation is available. However, the following questions remain to be answered.

1. Does water exist only in three discrete zones, or does some water move through other parts of the formation as well?
2. Are there pathways of interconnected fractures from the center of the site to the Pecos River through which transport may be much faster than the average transport time computed assuming an equivalent porous medium?
3. Are there karst channels through the Rustler?
4. What is the mechanism of removal of salt from the Rustler Formation?
5. What is a reasonable explanation for the variations in the chemical composition of Rustler water at the WIPP site, south of the site, and in Nash Draw?

The results of field testing and analyses conducted so far provide partial answers to these questions. The Department of Energy is planning to conduct additional testing and analyses over the next 2–3 years to answer these questions fully.

With respect to the front of "shallow" dissolution, the most conservative approach would be to take no credit for horizontal movement of this front, in other words to assume that the dissolution front has already moved over the site at the base of Rustler. Using the rate of vertical dissolution of 100 m per million years calculated by *Bachman* [1980], it would require 4.5 million years to remove 450 m of salt in the Salado above the repository horizon. Admittedly, these rates are very approximate, but they are based on conservative assumptions. There appears to be a sufficient margin of safety in the future direct breach of the repository through "shallow" dissolution of the type which has formed Nash Draw.

With respect to "deep" dissolution, as postulated by Anderson, it is very difficult to fix a rate of advance of the dissolution front. There is clear indication of missing salt from the lower Salado Formation, in the "Salt Dissolution Zone" of Figure 1. However, the mechanism of removal of salt is not well understood. Besides, according to *Anderson* [1982], the dissolution at depth may not proceed as a clearly defined "front," but the advanced effects of dissolution may be noticed along "fingers" much ahead of the dissolution front. The best way to determine the integrity of the WIPP site from this kind of dissolution is to examine the evidence from boreholes drilled at the site and surrounding it. Figure 1 shows the "deep dissolution" edges for the salt units, as interpreted by *Anderson* [1981]. It should be noted that the WIPP site is situated in the northern part of the basin, away from the dissolution fronts. The nearest point of the dissolution edge from the WIPP site is about 25 km away to the southwest (Figure 1).

There are five boreholes at the WIPP site (WIPP-9, 11, 12, 13, and DOE-1) which have penetrated the lowermost anhydrite bed (Anhydrite-I) in the Castile Formation. These holes have been cored at selected intervals, and geophysical logs for the entire depths have been obtained. In addition, three holes outside the WIPP boundary, AEC-7 and 8 to the northeast and ERDA-10 to the southwest, were drilled, cored, and logged through the Castile Formation. None of these eight boreholes (Figure 3), and none of the several industry boreholes around the WIPP site, show any evidence of extensive dissolution. This points to the fact that at least the immediate area surrounding the WIPP site has not been affected by deep dissolution. Even if the rate of advance of "deep" dissolution was the same as the "shallow" dissolution of *Bachman* [1980] (i.e., 10–13 km per million years) the site appears to be safe for the next 2 million years.

A borehole located 3.25 km north of the center of the site, drilled to assess the occurrence of potash minerals in middle Salado, encountered the Salado marker beds at elevations about 23 m below their expected occurrences. This anomalous depression has been confirmed by the logs of two other boreholes and has been suggested as a possible site of deep dissolution. The Department of Energy has accepted EEG's suggestion to drill a borehole to test the origin of this depression. This borehole, to be called DOE-2, will be drilled and cored down to the Bell Canyon Formation. The work is planned for 1984. One more anomalous feature has been pointed out near the WIPP site. About 8 km southeast of the center of the WIPP site, the accoustic log of a well shows that 60 m of a salt bed in the lowest part of the Salado Formation may be missing. Since this well is outside the WIPP boundary and is one unconfirmed anomaly out of a large number of wells, EEG has not made any recommendations to explore this feature further.

Approximately 3000 m of underground drifts at the selected repository level 655 m below the surface have already been excavated at the WIPP site. This excavation has been conducted to validate the site characterization under the site and preliminary design validation (SPDV) program. The thickness and continuity of strata displayed in this excavation are remarkably uniform, and there is no indication of dissolution either at the repository horizon or in cores of 15 m vertical boreholes drilled from the floor and ceiling of the excavation.

Conclusions

There are two main areas of concern with regard to the suitability of the WIPP site. The characteristics of the water-bearing zones of the Rustler Formation should be understood very thoroughly to preclude any possibility of these zones acting as pathways for migration of radionuclides to the biosphere. In addition to hydrologic testing already completed during the past 8 years, additional drilling and field testing is planned over the next 2–3 years. These forthcoming studies include the drilling and testing of several new hydrologic wells, drilling of new wells near existing hydrologic wells to convert at least eight single wells to sets of three-nested wells for tracer-tests and flow tests. The study of cores and determination of hydrologic properties from the cores as well as more geochemical testing of Rustler Formation waters are also planned. The data gained from these studies will be used to refine a hydrologic and contaminant transport model of the Rustler aquifers. In addition, a water-balance study for the site will be conducted and some suspicious depressions on the site would be bored to see whether they are alluvial dolines. Another study will try to answer the question of the mechanism of salt removal from the Rustler Formation. These studies will help to resolve the question concerning the possibility of karst conditions in the Rustler Formation.

The second area of concern is the effect of dissolution of salt on the integrity of the repository. The Salado Formation does not appear to have been affected in and around the WIPP site by past dissolution. The suspicion of an area of point-source dissolution from below, located 3.25 km north of the center of the site, will be investigated. Although stratabound dissolution of the Rustler salt occurs across the WIPP site, such dissolution does not seem to have affected the top of the Salado Formation at the WIPP site. However, the collapsed depression of Nash Draw is only about 6.5 km west of the center of the site. It is therefore important to understand thoroughly the mechanics of removal of salt from the Rustler Formation.

The mission of WIPP calls for the permanent emplacement of transuranic waste which would be reduced to a level of radioactivity of natural uranium ore in less than 100,000 years. The site selected for WIPP has been characterized sufficiently to enable the analyses of worst case scenarios of breach of the repository and consequent release of radioactivity. However, a few gaps remain in our knowledge of the geologic and hydrologic characteristics of the site which relate to the transport of radioactivity to the biosphere in the event of a breach. Additional field work to close these gaps is being performed currently and will be completed before the waste is brought to the site in 1989. If the additional work indicates a possibility of release of hazardous quantities of radioactivity to the biosphere, the EEG will recommend additional engineered barriers or investigations for a new site.

Acknowledgments

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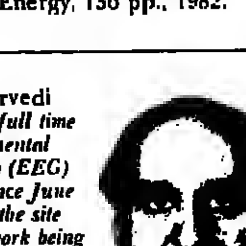
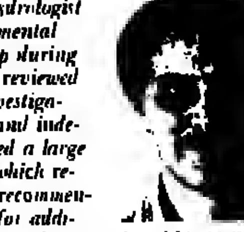


Lokesh Chaturvedi *has been working full time with the Environmental Evaluation Group (EEG) of New Mexico since June 1982 to evaluate the site characterization work being conducted by DOE for the WIPP project. His involvement with WIPP began in 1979 when he started working as a consultant to EEG while he was a professor of geological engineering at New Mexico State University. He has a Ph.D. degree in geological sciences from Cornell University, M.S. in civil engineering from Purdue University, M.Sc. in geology from Roorkee University (India) and a bachelor's degree in geology, physics, and math from the University of Rajasthan (India). He has taught at Michigan Tech., Indian Institute of Technology, City University of New York, and New Mexico State University. Before becoming involved in the site characterization for nuclear waste disposal, his research work was in geothermal hydrology and remote sensing for which he has conducted field work in Iceland, Himalayas, and the western United States.*



Kenneth R. Rehfeldt *worked as a geohydrologist with the Environmental Evaluation Group during 1982–1983. He reviewed the hydrologic investigations for WIPP and independently analyzed a large amount of data which resulted in EEG's recommendations to DOE for additional hydrologic work. He recieved his M.S. in hydrology from the New Mexico Institute for Mining and Technology and his bachelor's degree in geological sciences from the University of Wisconsin-Milwaukee. He is currently working toward his Ph.D. at the Massachusetts Institute of Technology and is conducting research in defining the controlling mechanisms of solute transport processes in groundwater.*

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Cover. This photograph, looking eastward to the new lobe on the west side of Mount St. Helens' composite dome, was taken on June 18, early in a recent extrusion episode. By July 1, the lobe had overfilled the 50-m-wide notch. For additional information on the Mount St. Helens extrusion, see the excerpts from the monthly bulletin of the Smithsonian Institution's Scientific Event Alert Network (SEAN) in the news section of this issue. (Photograph taken by Tom Casadevall, U.S. Geological Survey, Cascade Volcano Observatory, 5400 MacArthur Blvd., Vancouver, WA 98661; photograph courtesy of SEAN.)

News

Greenhouse Hydrology

A new report by the Environmental Protection Agency (EPA) takes predictions about life in the "greenhouse" future one step farther by analyzing the possible effects a buildup in atmospheric carbon dioxide would have on the hydrologic cycle. While principal authors David Rind and Sergej Lebedeff of the National Aeronautics and Space Administration (NASA) Goddard Institute for Space Studies in New York warn that their computer models are "only the first step in the process of planning for future changes," they suggest that a greenhouse warming would cause "substantial changes throughout the hydrologic cycle."

The study focuses specifically on changes in hydrologic conditions such as precipitation, evaporation, soil moisture, and runoff that would accompany a twofold increase in atmospheric CO_2. The Goddard model produces an atmospheric warming of 4.1°C for this doubling, which is at the high end of the range predicted by National Academy of Sciences studies (*Eos*, November 15, 1983, p. 929, and August 17, 1982, p. 609).

The researchers first looked at large-scale variables for the entire North American continent, such as annual average precipitation and evaporation. "To be useful to decision makers," however, the report states, "projections of hydrologic changes must also be tied to specific locations. . . . This study seeks to address these issues by examining possible changes in specific hydrologic characteristics including ground moisture, length of growing season, frequency and severity of droughts, runoff, and ground moisture."

Using the Goddard general circulation model (GCM), a computer simulation of the physical forces that affect weather, the researchers first made a control computer run based on existing hydrologic and atmospheric conditions, then compared these results with the output when the atmospheric CO_2 was doubled. Also factored into the computer models were observed hydrologic conditions during a particularly cold period (1900–1920) and a particularly warm period (1940–1980). The double CO_2 model was integrated for a period of 35 years, enough time, according to the authors, to produce an equilibrium climate. When the "greenhouse" model was run, the researchers saw a general pattern of increased precipitation in the north and northwestern parts of North America. Evaporation also increased by 15–20% in the northern and western parts of the continent and by 11% worldwide, similar to the percentage increases for rainfall. Runoff increased over the northwestern and extreme southwestern parts of the continent by as much as 20–60%.

In order to minimize computer time, the researchers divided North America's weather into large "grid areas" approximately 27,000 km square, and so were not able to consider the specific effects of different topographical features on the weather. As a result, they point out, the current computer model is able to accurately recreate existing climatic conditions "only at a very aggregate level."

But the modeling work needs to continue, say the authors of the report, which is entitled "Potential Climatic Impacts of Increasing Atmospheric CO_2 with Emphasis on Water Availability and Hydrology in the United States." "This report, in effect, presents a methodology for estimating the hydrologic impact of increased atmospheric CO_2," they state in their introduction, "and should be looked upon as a first approach to a complex problem."—*TR*

Space Telescope Studies

Definition studies for the Advanced X Ray Astrophysics Facility (AXAF), an orbiting X ray telescope to be launched from the space shuttle in the early 1990's, have been initiated by NASA. The space agency selected two California aerospace companies—TRW and Lockheed Space and Missiles—to conduct the 2-year studies of spacecraft hardware and science instrument requirements, after which time one of the two will be awarded a contract to build the telescope.

The AXAF facility will be the newest and most sophisticated in a series of X ray astronomical satellites dating back to the Uhuru satellite launched in 1970. Because the earth's atmosphere absorbs most incoming X ray radiation, telescopes sensitive to those wavelengths must be placed in orbit to be of value to astronomers. The AXAF will weigh approximately 9000 kg and will measure 4.28 x 13 m. Orbiting the earth at an altitude of 515 km, it will carry a number of instruments suited to the study of astronomical X ray sources, among which are active galaxies and suspected black holes. The observatory is expected to see X ray sources 100 times fainter than those seen by the HEAO-2 (High Energy Astronomy Observatory) launched in 1978, and will represent a significant improvement over the European EXOSAT now in earth orbit, particularly in its long operational lifetime, which is now expected to be about 15 years.

Lockheed and TRW are each receiving $4 million for the definition studies and will investigate the types of science instruments needed for the telescope and the spacecraft hardware configurations required to support them. The heart of the observatory will be a nested series of concentric, cylindrical mirrors that will focus X rays onto the imaging detectors of the various science instruments mounted within the telescope cylinder. Like the Hubble Space Telescope now planned for launch in 1986, the AXAF would be operated as a national observatory to be used by the entire astronomical community.

Science Policy Studied in Congress

The House Science and Technology Committee will initiate a comprehensive study of science policy in the United States. Although the study will not formally begin until January, when the 99th Congress convenes for its 2-year term, a newly appointed task force has begun to develop the agenda for the committee's work and has begun to prepare background information for the study.

Don Fuqua (D-Fla.), chairman of the Science and Technology Committee, said that the health and vitality of American science unquestionably has been a major factor in the strong performance of the American economy over the last 35 years. However, the committee is concerned that present policies and practices may not be fully adequate to the new environment facing U.S. science in the coming decades.

Among the issues that are expected to be on the agenda are the institutional framework for the support and conduct of scientific research; the training and education of young scientists; methods of funding research; and the overall funding levels for science.

The task force, to be composed of approxi-

News *(cont. on p. 460)*

News *(cont. from p. 459)*

mately 18 of the representatives on the House committee, will meet several times during the next few months. Its first meeting is scheduled for August 2. A report will be prepared by the end of the year. House Science and Technology Committee Executive Director Harold Hanson will be coordinating the study. John Holmfeld will provide staff support for the task force.

Upcoming Hearings In Congress

The following hearing has been tentatively scheduled for the coming week by the Senate and House of Representatives. Dates and times should be verified with the committee or subcommittee holding the hearing; all offices on Capitol Hill may be reached by telephoning 202-224-3121. For guidelines on contacting a member of Congress, see *AGU's Guide to Legislative Information and Contacts* (*Eos*, April 17, 1984, p. 159).

July 31, August 1, August 2: Hearing on the status, trends, and plans for the operations management and use of the space transportation system by the Space Science and Applications Subcommittee of the House Science and Technology Committee. Rayburn Building, Room 2325, 9:30 A.M.—*BTR*

Beardmore Glacier Proposals Wanted

Proposals for research projects to be conducted in the upper Beardmore Glacier area of Antarctica during the 1985–1986 field season are being accepted by the National Science Foundation (NSF) through August 16. Later proposal submissions should be discussed with the appropriate program managers (see below).

A temporary camp with helicopter support will be established in the region. Occupation by scientific parties will likely be between mid-November 1985 and mid-January 1086. Transportation in the field will be by UH 1-N twin-engine Huey helicopters (with a range of approximately 185 km) and by motor toboggans. Satellite tent camps will be established within the range of the helicopters. The exact position of the main camp will be determined in November. Likely candidates, however, are Buckley Island Quadrangle, in the area of the Walcott Névé or the Bowden Névé, near Coalsack Bluff or Mount Sirius.

A workshop was held at the University of Maine May 25–26 on the potential for a remote field camp in the area. A report entitled, "The Beardmore Glacier Remote Field Camp," was prepared by George H. Denton of the University of Maine, and by James W. Collinson and David H. Elliot, both of The Ohio State University. Copies of the report are available from Peter J. Anderson, Institute of Polar Studies, The Ohio State University, 125 South Oval Drive, Columbus, OH 43210 (telephone: 614-422-6531). Include $2 to cover copying and postage.

Pamphlets and kits on the preparation of proposals for research in Antarctica for NSF are available from the NSF Division of Polar Programs, 1800 G Street, N.W., Washington, DC 20550. Those contemplating submitting proposals later than August 15 or those having specific questions regarding research opportunities, budgets, or logistics should telephone the appropriate program manager: Mort D. Turner (polar earth science), Richard L. Cameron (polar glaciology), or Richard Williams (polar biology and medicine) (telephone: 202-357-7894).

Pleiades Wind

Astronomers studying the star Hz1883, located in the cluster of young stars called the Pleiades, report that they have found evidence that the star is pouring out an extremely strong stellar wind from an active emission region roughly one solar radius in size. The rapidly spinning star is losing angular momentum as a result of this steady outward stream, and so is slowing its rotation. Geoffrey Marcy and Douglas Duncan of the Mount Wilson and Las Campanas Observatories and Ross Cohen of the University of California at San Diego wrote in a paper delivered to the American Astronomical Society in Baltimore in June that, "It seems plausible that a succession of rapid rotation, mass loss, and subsequent spin-down constitutes a natural, though transient, stage in the evolution of late-type stars."

The astronomers arrived at this explanation for the star's behavior after they detected periodic changes in the shape and symmetry of its H-alpha spectral signal, changes conforming to the short rotation period. The changes were greater that what could be explained solely on the basis of the velocity of the star's surface, however. The astronomers concluded from the alternating redward and blueward shifts and from other evidence that the emitted material forms a stellar wind with oppositely directed streams whose high velocities cause the excessive wavelength shifts. —*FR*

June Streamflow

Flows of the nation's key index gauging streams were at average to well-above average levels for June across much of the country, according to a regular check on the condition of the nation's water resources by the U.S. Geological Survey (USGS).

USGS hydrologists said that of the 170 key index gauging stations nationwide, flows at 66 sites (39%) were well above average for June, 85 sites (50%) were in the normal range, and only 19 sites (11%) were well below average.

Although most of the northern United States experienced a wet June, low flow persisted in Texas, and dry conditions developed in much of the southeast and in the Ohio River Valley.

Reflecting overall conditions in June, the combined average flow of the nation's three major rivers was 1,184 billion gallons per day (bgd), 38% above the seasonal average. The Mississippi, St. Lawrence, and Columbia rivers together drain more than half of the lower 48 states, and their flows provide a convenient check on the status of the nation's water resources.

Record high monthly average flows for June occurred in Iowa, Kansas, Minnesota, Nebraska, and Nevada. The Humboldt River at Palisade, Nev., for example, set a record for June of almost 3 bgd, the highest flow in 77 years of record. The Humboldt River has been in the above-normal range—within the highest 25% of historic record—now for 24 straight months.

Record low or near record low flows were recorded in Hawaii, Idaho, Louisiano, and Texas. Extremely dry conditions prevailed in parts of Texas, with zero average flow of the North Concho River near Carlsbad, the lowest in 37 years of record. Barely 200,000 gallons per day of flow were recorded on the North Bosque River near Clifton, Tex., the lowest June flow in 61 years of record.

Flows of five of the nation's largest rivers for June: Mississippi River at Vicksburg, Miss., 598 bgd, 69% above average, despite a 36% decline from the average May flow; the Columbia River at The Dalles, Ore., 386 bgd, 17% above the long-term average for June and up 64% over last month; the St. Lawrence River near Massena, N.Y., 200 bgd, 10% above average, about the same flow as May; the Missouri River near Hermann, Mo., 137 bgd, 146% above average and up 3% from May; and the Ohio River at Louisville, Ky., 53 bgd, 31% above the June average, although flow declined by 63% from May. (Map courtesy of USGS, Reston, Va.)

Geophysical Events

This is a summary of *SEAN Bulletin*, 9(6), June 30, 1984, a publication of the Smithsonian Institution's Scientific Event Alert Network. The complete bulletin is available in the microfiche edition of *Eos* as a microfiche supplement or as a paper reprint. For the microfiche, order document E84-007 at $2.50 (U.S.) from AGU Fulfillment, 2000 Florida Avenue, N.W., Washington, DC 20009. For the paper reprint, order *SEAN Bulletin* (giving volume and issue numbers and issue date) through AGU Separates at the above address; the price is $3.50 for one copy of each issue number for those who do not have a deposit account, $2 for those who do; additional copies of each issue number are $1. Subscriptions to *SEAN Bulletin* are available from AGU Fulfillment at the above address; the price is $18 for 12 monthly issues mailed to a U.S. address, $26 if mailed elsewhere, and must be prepaid.

Volcanic Events

Merapi (Java): Explosions, nueés ardentes, lahars; 1000 evacuated.

Tinakula (Santa Cruz Is.): Tephra ejection; W flank submarine cone recognized.

Rabaul (New Britain): Seismicity declines; deformation continues.

Manam (Bismarck Sea): Strombolian activity; debris avalanches.

Langila (New Britain): Occasional ash emission; seismicity weak.

Campi Flegrei (Italy): Seismicity and uplift continue; socio-economic impact discussed; increased submarine fumarolic activity.

Etna (Italy): Explosions and lava production continue from SE Crater; central crater explosions.

Kilauea (Hawaii): Phases 20–22; highest lava fountains of 1983–84 eruption.

Mount St. Helens (Washington): New lobe extruded into notch in dome's W flank (see cover photograph).

Atmospheric effects: Atmospheric turbidity over Japan declines gradually from late 1982 to early 1983 peak; lidar shows persistent aerosols.

Merapi Volcano, *Java, Indonesia (7.54°S, 110.44°E). All times are local (= UT + 7 hours).*

The quoted material below is excerpted from a report by Adjat Sudradjat.

"Merapi erupted June 15 between 0215 and 0600, accompanied by nuées ardentes that extended 7 km down rivers (the Batang, Bebeng, and Krasak) on the SW side of the volcano. An eruption plume rose to 6 km height and caused ashfall in Muntilan, Ambarawa, and Semarang, approximately 60 km north of the volcano. The eruption was accompanied by detonations. The first explosion was followed by a milder eruption producing a plume to 2 km height and a nuée ardente to 6 km distance at noon. The frequency of nuées ardentes progressively decreased until the morning of June 16. No eruptions were observed the following day. Lahar material estimated to exceed 4 x 106 m³ along the Bedeng, Krasak, and Putih rivers may threaten Magelang city (population about 125,000)."

Newspapers reported ashfalls at Magelang (30 km NW of Merapi) and Salatiga (35 km NE of the volcano). Visibility near Salatiga was limited to 10 m and more than a centimeter of ash covered roads, slowing traffic. More than 2 cm of ash fell at Solo (45 km E of the volcano), and ashfall was reported at Cilacap, on the coast 160 km SW of Merapi.

"Seismographs detected a progressive increase in seismicity from four counts per day June 8 to 59 on June 12. A warning was issued June 13 and the evacuation of 1,000 persons from forbidden zone section VI (Kemiren village) was immediately implemented. The tong-tong warning system was tested again to be sure that it was operational. The eruption was preceded by an intense lava avalanche on June 13 that caused a nuée ardente d'avalanche (nuée ardente of Merapi type)."

Information Contact: Adjat Sudradjat, Director, Volcanological Survey of Indonesia, Diponegoro 57, Bandung, Indonesia; The Jakarta Times, Jakarta, Indonesia.

Tinakula Volcano, *Santa Cruz Islands, SW Pacific Ocean (10.47°N, 165.75°E).*

The following is from the cruise report of the USGS research vessel *S. P. Lee*, engaged in multichannel seismic profiling in the Vanuatu and Solomon islands areas.

"On June 3, Tinakula could be seen 'smoking' in the distance, some 25 km away. As the ship approached the island, large billowing clouds of steam were observed. At approximately 2-hour-intervals, a large billowing dark gray ash-laden plume was observed rising to several kilometers above the island. The *S. P. Lee* passed within 400 m of Tinakula along the N side of the island. Rumbling sounds could be heard from within the active vent, immediately north of the central crater. Boulder-size rocks were ejected from the vent and were still steaming as they rolled and skipped down the steep scree slope into the sea. At least a dozen or so of the boulders and much more material of cobble size were seen being thrown from the vent every minute. Much of this debris was accumulating on the scree slope.

"Geophysical data collected by the *S. P. Lee* showed that another volcanic cone is present about 90 m beneath the surface of the water some 5 km W of Tinakula. It has sharp steep flanks, and appears from its morphology to

be active. This volcano or volcanic vent has not been identified before and is not on any bathymetric map."

Tinakula's last reported eruption occurred September 6 to December 11, 1971. Intermittent explosive activity built a small summit cone; incandescent blocks rolled down the volcano's flanks; and a slow-moving lava flow extended about 300 m down the NW flank.

Information Contacts: A. Macfarlane, Director, Department of Geology, Mines, and Rural Water Supplies, GPO, Port Vila, Vanuatu; H. G. Greene, Branch of Pacific Marine Geology, USGS, 345 Middlefield Road, Menlo Park, CA 94025.

Mt. St. Helens Volcano, *Cascade Range, S Washington, USA (46.20°N, 122.18°W). All times are local (= UT—7 hours).*

The quoted material is from Peter Otway.

A new lobe in the composite lava dome began to emerge in mid-June. Its location, on the W flank, was within the notch that was the source of explosions on May 14, 26, and 27 and June 6 (see *SEAN Bulletins*, vol. 9, nos. 4–5) as well as a similar event on June 7 (see below). Growth of the west flank lobe had stopped by July 1. Accelerating deformation on the dome's north side was measured in late June and early July, but rates of deformation began to decrease after several days and no lava reached the surface.

A small explosion occurred June 7 at 1720 when airline pilots observed an ash cloud that rose to about 9 km altitude. Increased water flow from the crater began at about 1740, and a mudflow about 3 m wide and 15 cm deep reached Spirit Lake (5.5 km from the crater) at 1802.

Beginning June 14–15, the number of earthquakes at the nearest crater seismometer (Yellow Rock) increased from about 20–30/day to 50–60/day, and the number of surface (rockfall) events began to increase June 16–17. The small new lobe was first seen during the afternoon of June 17 (by gas monitoring aircraft pilot Al Maris), and was more clearly visible during an overflight at 2230 that night.

"When first tracked, on June 18, the leading edge of the lobe, was moving down slope at over 30 m/day, although rates near the extrusion site were at least 50% higher. By June 22, movement of the leading edge had slowed to 13 m/day, and by June 25, to 6 m/day. When next observed, on July 1, the flow had stopped. The lobe is 60 m wide at its maximum and 150 m long. Its volume is estimated to be on the order of 0.2 x 108 m³.

"Targets on the north side of the dome moved north/northeast at rates which steadily increased to 60 mm/day by June 25. Movement then swung to the north as rates accelerated rapidly to peak at 0.8 m/day between June 30 and July 2. By July 10, the rates had fallen to 20 mm/day. This suggests that an intrusive event occurred late in June at a site at least 100 m east of the mid-June extrusion."

Rates of SO_2 emission ranged from 15 to 35 metric tons per day (near the detection limit) during the first 2 weeks of June. The next measurement, during the morning of June 18, was 105 metric tons per day. Rates averaged about 100 tons per day through July 1, but had dropped to 40 tons per day by July 6.

Information Contacts: Steven Brantley, Tom Casadevall, Eliot Endo, Clint Mullins, Chris Newhall, and Peter Otway, USGS Cascades Volcano Observatory, 3400 MacArthur Blvd., Vancouver, WA 98661; Robert Norris, Geophysics Program, University of Washington, Seattle, WA 98195.

Meteoritic Events

Fireballs: Arizona, Arkansas, Iowa, USA.

Earthquakes

Date	Time, UT	Magnitude	Latitude	Longitude	Depth of Focus	Region
June 24	1117	6.5 M_s	18.03°N	69.33°W	shallow	S of Hispaniola

Correction

The following corrections to the article, "The Lunar Core and the Origin of the Moon," by Horton E. Newsom, which was published in *Eos*, p. 369, May 29, 1984, *were not included* in the *published* version. A corrected version of the article will appear in the shelf editon of *Eos*.

1. The author's name was misspelled. It should be Horton E. Newsom.
2. The author's current address is Institute of Meteoritics and Department of Geology, University of New Mexico, Albuquerque, NM 87131.
3. In Table 3, P/Nd C1 value is 2,100.
4. Among some references not included with the published version was a reference for A. E. Ringwood and S. E. Kesson, Basaltic magnetism and the bulk composition of the moon, 2, Siderophile and volitile elements in moon, earth and chondrites: Implications for lunar origin, *Moon, 16*, 425–464, 1977.
5. Dr. Newsom would like to acknowledge A. E. Ringwood, whose additional suggestions were not included in the published version. The modern concept of a terrestrial origin for the moon remains indelibly stamped with Ringwood's name.

Classified

RATES PER LINE

Positions Available, Services, Supplies, Courses, and Announcements: first insertion $5.00, additional insertions $4.25.

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Replies to ads with box numbers should be addressed to Box ___, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, DC 20009.

For more information, call 202-462-6903 or toll free 800-424-2488.

POSITIONS AVAILABLE

Project Associate/Specialist: Electron Micro-Probe Lab, University of Wisconsin-Madison. Strong analytical background in quantitative EMP analysis and familiarity with computers is required. The Lab has a 9-spectrometer ARL SEMQ and a JEOLCO 50-A SEM. Duties will include instrument maintenance, instruction of students, development of procedures and analysis. Research will be encouraged. A MS or PhD is required in Earth Science, Chemistry, Physics or Engineering. Minimum salary will be $18,000/12 months with an MS. Send letter of application, transcripts, resume, and names and addresses of three references by September 15 to Dr. John W. Valley, Department of Geology & Geophysics, Weeks Hall, University of Wisconsin, Madison, WI 53706.

An equal opportunity employer.

Hydrogeologist/Texas A&M University. The Department of Geology and Center for Engineering Geosciences have a tenure track opening, preferably assistant professor level, for which the first search will be for a creative individual working in applied geological hydrology.

The successful applicant will be expected to develop teaching and research recognition at a national level. The position is available beginning September 1, 1964 and will be held open until filled. Applicants should submit a vita including names of references to M.C. Gilbert, Department of Geology, Texas A&M University, College Station, TX 77843.

Texas A&M University is an affirmative action/equal opportunity employer.

Bedford and Royal Colleges/Lectureship in Geology. Applications are invited for a new lectureship in the department being created by the amalgamtion of the geology departments of Bedford, Chelsea and King's Colleges. The field of specialization and level of appointment is open but a very strong interest and/or considerable experience of radiogenic isotope geology is essential. Gross salary range (under review) £8,376—£15,311 p.a. Further particulars and application form (returnable by 14 September) may be obtained by sending s.a.e. to Personnel Secretary, Bedford College, Regent's Park, London NW1 4NS, England.

Postdoctoral Position/University of Arizona. A postdoctoral position has been opened at the Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona, in July 1984. The research is in the general area of space and planetary physics with much of the work related to Voyager EUV observations at the outer planet encounters. The program includes work in plasma physics concerned mostly with the fundamental nature of the Io plasma torus, upper atmospheric and auroral processes on Jupiter, Saturn, Titan, Uranus and Neptune, exosphere-magnetosphere modelling at Saturn, and some specialized aspects of the interstellar-interplanetary medium. The applicant should have a background in atomic and molecular physics with an interest in planetary atmospheres. Applications should contain vita, statement of interests, and names of three references, and should be submitted by August 30, 1984. Further information can be obtained by contacting D. E. Shemansky, Lunar and Planetary Laboratory, 3625 E. Ajo Way, Tucson, Arizona 85713; 602-621-4301.

The University of Arizona is an equal opportunity/affirmative action employer.

Princeton University. The Department of Geological and Geophysical Sciences invites applications for a tenure track appointment beginning September 1, 1985, at the Assistant Professor level in the area of Isotope Geology with specialization in $^{40}Ar/^{39}Ar$ mass spectrometry.

Candidates must be thoroughly grounded in the fundamentals of isotope studies (stable and radiogenic) and their application in earth science, and have demonstrated an ability for research in this or related fields. The appointee will be expected to supervise our newly assembled continuous-laser-heating Argon age laboratory, and to participate in collaborative research programs using this facility. Teaching duties are to complement and expand the existing programs.

Applicants should send resume and names of three referees to Robert A. Phinney, Chairman, Department of Geological and Geophysical Sciences, Princeton University, Princeton, N.J. 08544.

Princeton University is an equal opportunity/affirmative action employer.

RESEARCH ENGINEER

Scripps Institution of Oceanography has an opening for a research engineer to be responsible for major ocean development project in acoustics. Requires extensive experience in acoustics, oceanography, digital electronics systems designs, software and data processing. Acoustic experience must include hardware design as well as extensive ocean-going experimental work. Ph.D. level or equivalent required in one of above areas. Candidate should have experience as principal investigator and interaction with funding agencies, particularly Navy. U.S. Citizenship required. Salary range: $42,400–$51,200. Send curriculum vitae and names of references to:

K. M. Watson, Director
or
F. H. Fisher
Marine Physical Laboratory
Scripps Institution of Oceanography
University of California
San Diego, California 92152

Closing date: 31 August 1984.

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NATIONAL SCIENCE FOUNDATION (NSF)

NSF's Division of Earth Sciences is seeking qualified applicants for the position of Program Director for the Seismology Program. The position is excepted from the competitive civil service and will be filled on a one- or two-year rotational basis. The salary ranges from $40,000 to $66,400 per annum. The program supports basic research in projects related to observational, laboratory, and theoretical studies directed at a thorough understanding of the earthquake process, how seismic waves propagate in the earth, and the determination of earth structure from seismic observations. Applicants should have a Ph.D. in Earth Sciences or equivalent experience in addition to six to eight years of successful scientific research in seismology beyond the Ph.D. Demonstration of extensive research experience and productivity could be used as equivalence to a Ph.D. A broad general knowledge of geological and geophysical research and familiarity with the U.S. scientific community are also required. Applicants should refer to Announcement No. EX 84 53EOS when submitting resumes to the National Science Foundation, Personnel Administration Branch, Rm. 212, 1800 G Street NW., Washington, DC 20550. Attn: Catherine Handle. For further information call 202/357-7840. Hearing impaired individuals should call: TDD 202/357-7492.

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Physical Oceanography/Acoustics. Research Scientist positions are available for versatile and innovative individuals with capabilities in the following areas:

OCEAN ACOUSTICS AND/OR SIGNAL PROCESSING. Candidates at both entry and experienced levels are sought. Analytical and experimental positions are available in the fields of acoustics, seismoacoustics and geophysics, remote sensing and image processing. Ph.D. or M.S. required.

PHYSICAL OCEANOGRAPHY. Ph.D. or some experience preferred. Positions involve both analytic modeling and analysis of small-scale hydrodynamic processes in the ocean. Experience with internal waves, finestructure or microstructure is desirable.

Submit resume and salary requirements to: Fern Marks, Manager of Administration, Dynamics Technology, Inc., 21311 Hawthorne Blvd., Suite 300, Torrance, CA 90503.

Equal Opportunity Employer—M/F—U.S. Citizenship Required.

University of Texas at Austin. The Department of Geological Sciences invites applications for a person to teach depositional systems and petroleum geology at the undergraduate and graduate levels and to conduct a vigorous research program, including the supervision of graduate students, in the area of the person's interest. The person must be willing to teach the above subjects to non-majors on occasion. The position requires the Ph.D. and is open to both tenure seeking junior persons and senior-level persons. Availability by January 1985 is desirable. Applicants should submit a detailed resume, names and addresses of five references, and a statement of teaching and research interests by November 1, 1984 to Dr. Earle F. McBride, Department of Geological Sciences, University of Texas, Austin, Texas 78712. New Ph.D.-holders should also submit a copy of their dissertation abstract.

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Geochemist. The University of California, Davis, Department of Geology, has an opening for a one year temporary faculty position for Fall 1984. Specific fields are open; however specialization in isotope and economic geochemistry are desirable. The Department has strong programs in paleobiology, paleoceanography, petrology, geophysics, and crust and mantle evolution. A Ph.D. is required. Responsibilities include graduate and undergraduate teaching and research in geochemistry.

Applicants should submit vita, statement of research and teaching interests, and the names of three references as soon as possible, as the position is for the Fall, 1984 quarter.

We anticipate that this position will be opened on a permanent, tenure track basis during the next academic year. A successful candidate for this temporary position can apply for the tenure track position. Inquiries and applications should be sent to Chair, Search Committee, Department of Geology, University of California, Davis, Davis, California 95616.

The University of California is an equal opportunity/affirmative action employer.

Scripps Institution of Oceanography, Geological Research Division: Postdoctoral Research Stable Isotopes/Sedimentology. Applications are invited for a postdoctoral position in the Geological Research Division of SIO. We are looking for candidates with a strong background in chemistry, and an interest in paleoceanography, paleoclimatology, or carbonate geochemistry and sedimentology. Preference will be given to persons experienced in the operation and maintenance of mass spectrometers. Level of appointment and salary will be commensurate with experience, according to University of California standards. Applications and curriculum vitae (2 copies), and references, should be addressed to Drs. W.H. Berger or M. Kastner, Scripps Institution of Oceanography, La Jolla, CA 92093, A-015, before August 15, 1984.

Electrical Engineers/Computer Professionals/Systems Analysts/Physicists/Mathematicians. Systems & Analytical Sciences, Inc., a young dynamic company, invites applications from BS/MS/PhD degree holders to fill many positions. Experience in Signal Processing, hardware/software development, Communication Systems R&D, Systems Analysis, Numerical and Simulation studies, Remote Sensing, Meteorology, Space Sciences and related fields. U.S. Citizenship required but not a must. Excellent salaries and unparalled company paid benefits offered. Please send resume to: Mr. Charles Gillis, Director of Marketing, Systems & Analytical Sciences Inc., Hanscom Civil Air Terminal Building, Bedford, MA 01731.

Faculty Positions in Geophysical Sciences/The University of Chicago. The Department of the Geophysical Sciences invites applications for positions at all levels across the entire range of earth and planetary sciences, including meteorology and oceanography. Particular attention will be given to applications in interdisciplinary areas with prospects of major advances in observation, theory and application. Please send resume and reprints to Joseph V. Smith, Chairman, Appointments Committee, 5734 South Ellis Avenue, Chicago, Illinois 60637, USA. Applications will be considered rapidly throughout the year.

The University of Chicago is an equal opportunity/affirmative action employer.

Senior Research Associate in Physical Oceanography/University of Miami. Available for research in air-sea and air-sea-ice interactions as they relate to variations in climate and fish stock recruitment. Renewable one-year appointment. Salary negotiable based on experience. Announcement closes 1 September 1984. Applicants should send a resume and three references to:

Dr. William Fox
Chairman, Search Committee
University of Miami—CIMAS
4600 Rickenbacker Causeway
Miami, FL 33149
305-361-4185.

An Equal Opportunity/Affirmative Action Employer.

Postdoctoral Fellowship/Geophysical Institute, University of Alaska, Fairbanks. Ph.D. in Physics with extensive course work in all areas of Physics. Preference will be given to candidates with some experience in one or more of the following: 1) experimental work in infra-red spectroscopy, 2) digital electronics, and 3) numerical modeling. Work will involve field observations of airglow and auroral emission analysis and some teaching. Salary at least $34,800/year D.O.E. One year appointment with renewal of up to two more years. Write to: Dr. Abas Sivjee, Geophysical Institute, C.T. Elvey Building, University of Alaska, Fairbanks, AK 99701. Deadline for applications: 8–31–84.

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Science Writer. AGU is expanding the Eos staff and has an immediate opening for an experienced reporter/writer. Candidate must be able to research, interpret, and write on new scientific research, trends, and/or results for readers. Will also prepare timely reports on the effects of government legislation on the science community and the general public. In addition, candidate will be expected to participate in AGU's developing public information activity. Salary $19,000—$23,000. Send resume with news writing samples to:

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Call for Papers
Silicic Domes

Manuscripts are requested for possible inclusion in Geological Society of America Publication on the emplacement of silicic domes and lava flows.

Deadline: October 31, 1984.

For more information, contact:

Jonathan Fink
Geology Department
Arizona State University
Tempe, Arizona 85287
(602) 965-3195.

NATO Advanced Study Institute/Large Scale Transport Processes in Oceans and Atmosphere. Les Houches, French Alps, February 11–22, 1985.

A primary objective of the course is to develop understanding of the large scale atmospheric dynamics, ocean dynamics and the interactions between ocean and atmosphere. The principal lecturers (Blackman, Gill, Hoskins, Rhines, Welander) will cover the above topics, starting at a relatively simple level and developing them to advanced research level. In addition, a number of more specialized lectures will be given by supporting lecturers.

The Institute is intended for graduate students or young postdoctoral researchers. Limited funding is available. Students should write to Dr. J. Willebrand, Institute for Meereskunde, Dusternbrooker Weg 20, D-2300 Kiel 1, W. Germany, for further information, as soon as possible.

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Teaching and/or Research – Geology, Paleontology, Geophysics, Mining and Petroleum Engineering. Extensive practical and teaching experience in the US and abroad. Specialist in resource exploration and development—multilingual with fluent Persian and Turkish. Salary and rank negotiable. Reply to Box 026, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, D.C. 20009.

Meetings

Announcements

NWS Users Meetings

September 1984 Meetings on NWS Status, various locations. Sponsor: NOAA. (Robert Garnahan, Chief, External Relations and Industrial Meteorology Staff, W×5, NOAA, National Weather Service, 8060 13th Street, Room 421, Silver Spring, MD 10910.)

The National Weather Service (NWS) will hold a series of meetings in September to help external users keep informed of its services on recent or planned developments within the National Oceanic and Atmospheric Administration (NOAA). The meetings will provide an opportunity for interaction between NWS representatives and user groups. Discussions will highlight technical and non-technical subjects, including NEXRAD, family of services, the remote radar weather display system, and model developments at the National Meteorological Center.

The 1-day meetings are scheduled as follows: September 11: New York, N.Y.; September 13: Kansas City, Mo.; September 18: Salt Lake City, Utah; and September 20: Fort Worth, Tex.

Managing Environmental Resources

October 15–19, 1984 Seminar on Interactive Color Graphics for Environmental Resource Management, Ithaca, N.Y. Sponsor: Cornell University. (Diane Banfield, Program Coordinator, Cornell University, Box 423 B12 Ives Hall, Ithaca, NY 14853; tel.: 607-256-4987.)

Emphasis will be on the uses of low-cost, high-resolution interactive color graphics work stations for solving common resource planning and management problems. Computer experience is not necessary. The program is designed for scientists, engineers, planners, analysts, educators, and technical management personnel.

Groundwater Contamination

October 29–30, 1984 Conference on Methods for Evaluation of Groundwater Contamination Sites, East Lansing, Mich. Sponsors: Michigan Dept. of Natural Resources, Michigan State University, Michigan Section of ASCE, USGS. (David Hamilton, Michigan Dept. of Natural Resources, Stevens T. Mason Building, Box 30028, Lansing, MI 48909.)

Methodology and analysis will be the emphasis of the 2-day conference. Topics to be discussed include site evaluation, gathering field data, interpretation of field data, groundwater modeling as a valuable tool, and the applicability of geophysical methods in field investigations. The discussions will be geared toward applications in Michigan's glaciated geology. The conference is designed to provide practical methods to the engineers and geologists who perform hydrogeologic analysis. Participants will be expected to have at least a basic background in hydrogeology and common field techniques.

Humid Tropics

November 12–17, 1984 First Symposium on the Humid Tropics, Belém, Pará-Brasil. Sponsors: Brazilian Agricultural Research Organization and the Center for Agricultural Research on the Humid Tropics, The National Council for Scientific and Technological Development, and the Ministry of Foreign Relations. (Secretaria do 1° Simpósio do Trópico Úmido, Centro de Pesquisa Agropecuária do Trópico Úmido-CPATU, Caixa Postal 48, 60000—Belém, Pará-Brasil; tel: 091-226-6622; telex: 91121.)

The deadline for papers (not to exceed 20 double-spaced typed pages) is August 31, 1984.

To discuss and evaluate the state of knowledge of the humid tropics, the following topics will be covered: soil, subsoil, climate, fauna, flora, use and conservation, food crops, industrial crops, cattle raising, pastures, forests, and socioeconomic aspects.

Water Resources Management

September 19–23, 1985 International Symposium on Scientific Basis for Water Resources Management, Jerusalem. Sponsors: Israel Association of Hydrology, IAHS. (SBWRM Israel '85, The Israel Association of Hydrology, P.O. Box 6381, Jerusalem, Israel.)

Abstracts of 2–4 pages are due September 30, 1984.

The objective of the symposium is to present and discuss topics in those areas of hydrology and water resources that provide the basis for decision making and management. Emphasis will be placed on the scientific basis for decision making, but the symposium will deal equally with understanding how knowledge of the basic phenomena serves to rationalize management.

Papers should address those issues and be designated explicitly as belonging to one of the following topics: forecasting (climate, hydrology, demands, economics); groundwater (management of quantity and quality); rivers, lakes, and reservoirs; ecology, biological systems, and environment; water quality (considerations for management); approaches and models for water resources management; or approaches and methodologies for water policy formulation and evaluation.

Crustal Extension

October 10–12, 1985 Conference on Heat and Detachment in Crustal Extension on Continents and Planets, Sedona, Ariz. Sponsor: Lunar and Planetary Institute, USGS, GSA. (Pam Jones, LPI Projects Office, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058; tel.: 713-486-2150.)

The abstract deadline is October 31, 1984.

The conference is aimed at exploring the role of thermal and mechanical crustal decoupling in controlling the tectonic style of extension on terrestrial continents and solar planets, using field and laboratory data as well as modeling considerations.

Attendance is limited to 75 people.

Coal Science

October 28–November 1, 1985 International Conference on Coal Science, Sydney, Australia. Sponsor: International Energy Agency. (R. W. Hinde, Executive Secretary, CSIRO, Division of Fossil Fuels, P.O. Box 136, North Ryde, NSW 2113, Australia.)

The deadline for abstracts is September 30, 1984.

Papers will be welcomed on the following topics: coal structure and characterization; basic reactions of coal; fundamentals of coal combustion and gasification; pyrolysis and its reactions and products; liquefaction; and beneficiation, storage, and transport.

Manuscripts of the papers accepted will be due in May 1985.

AGU Membership Applications

Applications for membership have been received from the following individuals. The letter after the name denotes the proposed primary section affiliation.

Regular Members

James B. Allen (GP), Jeffrey F. Bell (P), Paul J. Boison (H), David L. Bradley (O), Gerhard E. Brugman (V), Guy J. Consolmagno (P), Mostafa A. Foda (O), Diem Ho (A), Judith J. Liotta (V), Boon-Ghye Low (SS).

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Donald R. Althauser (H), Brian F. Aubry (H), Edward M. Baker (G), Patrick Black (H), Sandra C. Chapman (SM), J. Steven Dingman (O), Giday W. Gabriel (V), John C. Greer (T), Lynn M. Kistler (SM), Jay R. Lund (H), Jackie Lundy (S).

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Rebecca R. Schudlich (O), Jose Luis B. Sebra De Melo (O), Holly J. Stein (V), Eric W. Strecker (H), Ray Teng (V), Daniel Tormey (V), Sichee Tsay (A), Stephen R. Walbridge (H), Wayne Warburton (S), William R. Wise (H).

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Reviews of Geophysics and Space Physics
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Approximately 800 pages to be published in Volume 23, 1985.

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Nominations for Fellowship in the Union are being sought by the Fellows Committee and the Section Selection committees. Nominees for Fellowship should be scientists who have attained acknowledged eminence in a branch of geophysics. The total number of Fellows elected each year cannot exceed 0.1% of the total membership.

To be considered by the Committee, nominations for Fellowship in AGU *must be made on the form below.* If more space is needed, attach a separate sheet.

AMERICAN GEOPHYSICAL UNION
Nomination For Fellowship

Name of Nominee ____________ Name of Sponsor ____________

Personal Data on Nominee

Business Address (including position held) ____________

Date and Place of Birth ____________

Education (degrees, institutions, major field) ____________

Professional Record (including special honors) ____________

Membership in Other Scientific Organizations ____________

Attach a list of most significant publications (not abstracts, book reviews, or papers that have not yet been accepted for publication).

Sponsor's Evaluation of Nominee

Attach a supporting statement which must include: (1) an indication of the length and nature of your acquaintance with the nominee; (2) the nominee's contributions to the field to date; (3) your evaluation of the nominee's scientific ability; (4) a one-line citation, "For . . . .", summarizing why the nominee should be elected a Fellow.

Signed ____________ Date ____________

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For a list of current Fellows, write AGU.

Send nominations for forwarding to your designated Section Selection Committee to:

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Deadline: September 17, 1984

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Exploration Geophysics

0920 Magnetic and electrical methods
INVERSION OF BOREHOLE NORMAL RESISTIVITY LOGS
Peng-wei Yang (Ministry of Coal Industry, P.R.C.; on leave at Dept. of Geology and Geophysics, University of Utah, Salt Lake City, UT 84112) Stanley H. Ward

This paper reports on an investigation of the inversion of borehole normal resistivity data via ridge regression. Interpretation is afforded of individual thin beds and of complicated layered structures.

A theoretical solution is given for a layered model containing an arbitrary number of layers in the forward problem. Two forward model results for resistive and conductive thin beds indicate that for high-resistivity contrasts, the departure between true and apparent resistivity may be more important than the effects caused by the variations in borehole diameter and mud resistivity. Four normal resistivity logs were chosen to test the inversion scheme. Two of the logs were theoretical logs with and without random noise added, and the remaining two were field examples. Theoretical model results and field examples indicate that the inverse method can be used to obtain the resistivity for each layer when the boundary position is known, but it also can be used to obtain the thickness and resistivity for each layer simultaneously.
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0910 Seismic methods
COMPARISON OF P- AND S-WAVE SEISMIC DATA: A NEW METHOD FOR DETECTING GAS RESERVOIRS
Ross Alan Ensley (Exxon Production Research Company, P. O. Box 2189, Houston, TX 77001)

Compressional waves are sensitive to the type of pore fluid within rocks, but shear waves are only slightly affected by changes in fluid type. This suggests that a comparison of compressional- and shear-wave seismic data recorded over a prospect may allow an interpreter to discriminate between gas-related anomalies and those related to lithology. This case study documents that where a compressional-wave "bright spot" or other direct hydrocarbon indicator is present, such a comparison can be used to verify the presence of gas. In practice, the technique can only be used for a qualitative evaluation. However, future improvement of shear-wave data quality may enable the use of more quantitative methods as well.
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0910 Seismic methods
WAVE-EQUATION VELOCITY ANALYSIS
Alfonso Gonzalez-Serrano (Formerly Stanford University; currently Geosource Inc., 6906 Southwest Freeway, P.O. Box 36306, Houston, TX 77235) Jon F. Claerbout

Velocity sensitive (wide propagation angle) seismic data do not comply with the raw small propagation angle approximation. A hyperbolic velocity spectrum and Dix's equation cannot use wide-angle arrivals to estimate interval velocity accurately. The linear moveout method measures interval velocity exactly in stratified media. Snell midpoint coordinates are constructed to image the data before velocity estimation. Energy focuses at the arrival coordinates of a fixed reference Snell wavefront as required by the linear moveout method. The image of a common-midpoint seismic gather in Snell midpoint coordinates, for a conventional reference Snell wave, defines the wave-equation velocity spectrum. Two important properties of the velocity spectrum are locality, where energy is a local function of velocity; and linearity, that is invertible using linear transformations. Velocity sensitivity of wave-equation extrapolation operators increases with angle of propagation. In Snell midpoint coordinates, angles are measured relative to an arbitrary elected reference Snell wave. At this particular angle wave-equation operators are exact, independent of velocity. Approximations of the wave equation in Snell midpoint coordinates satisfactorily image wide-angle energy. To compute the velocity spectrum, we use the 15-degree finite-difference wave equation in the frequency domain. This equation is insensitive to the downward continuation velocity. This formulation resolves multivalued, wide velocity spectrum data using inhomogeneous, offset and depth dependent, downward continuation velocity. Stepout filtering concurrent with downward continuation eliminates wide-angle propagation energy not modeled by the 15-degree wave equation.
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Meteorology

1710 H_2O in the Atmosphere (Cloud Remote Sensing)
DETERMINATION OF CLOUD PARAMETERS FROM INFRARED SOUNDER DATA
S.-T. H. Yeh (Goddard Laboratory for Atmospheric Sciences, NASA/Goddard Space Flight Center, Greenbelt, Maryland, 20771)

A method for remote sensing of cloud parameters by using infrared sounder data has been developed on the basis of the parameterized infrared transfer equation applicable to cloudy atmospheres. The method is utilized for the retrieval of cloud height, amount, and emissivity in the 11 µm region. Numerical analyses and retrieval experiments have been carried out by using synthetic sounder data for the theoretical study. The sensitivity of the numerical procedures to the measurement errors are also examined. The retrieved results are physically discussed and numerically compared with the model atmospheres. Comparisons reveal that the recovered cloud parameters agree reasonably well with the pre-assumed values. However, for cases when relatively thin clouds and/or small cloud fractional cover within a field of view are present, the recovered cloud parameters show considerable fluctuations.

Experiments on the proposed algorithm are carried out utilizing High Resolution Infrared Sounder (HIRS/2) data of NOAA 6 and TIROS-N. Results of experiments are difficult to verify quantitatively, but the retrieved cloud amounts show reasonably good comparisons with the surface reports and GOES satellite images. (Cloud observations, satellite IR cloud sensing, NOAA-6, HIRS/2, TIROS-N).

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Water Resources Research

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